POLLEN ANALYSIS OF PAST VEGETATION AT POINT REYES NATIONAL SEASHORE, CALIFORNIA

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ABSTRACT

Pollen analysis indicates major vegetational changes near Wildcat Lake, Point Reyes National Seashore, California, in the last millennium. Changes in the relative proportions of grass and shrub pollen both before and after colonization imply that the proportions of grassland and scrub vegetation were not constant even before European colonization. Near the top of the sediment core the ratio of grass to shrub pollen increases. The simultaneous appearance of pollen of introduced plant species allows this level of the diagram to be dated historically at about 1850 A.D. Thus this increase in grasses may be correlated with increased grazing. A shift from abundant *Alnus* pollen to *Myrica* and *Salix* near the bottom of the core is interpreted as the result of a landslide that changed local drainage.

Agricultural and logging practices obscure precolonial vegetational patterns in the New World. Because the patterns are probably caused primarily by interactions of climate, soil and topography, their reconstruction is of considerable interest to ecologists. For example, the Mediterranean type of vegetation that characterizes western California has a fairly short history of active exploitation, generally less than 150 years. Near the coast, extensive short grass pastures are interspersed with shrubby vegetation, occasional small, bunch-grass prairies, and deciduous or coniferous woodlands. The mountain ridges parallel to the coast are mainly forested with *Pinus* spp. or *Pseudotsuga menziesii,* and many valleys east of these ridges in the northern and north-central parts of the state contain *Sequoia sempervirens* (Munz and Keck 1959, Ornduff 1974).

Probably the most active cultural exploitations are grazing and urbanization, which have nearly obliterated the natural vegetation of coastal prairie, dominated by grasses such as *Deschampsia holciformis, Calamagrostis nutkaensis* and *Festuca californica.* Grazing has also modified coastal scrub, dominated by shrubs such as *Rhus diversiloba, Rubus ursinus, Artemisia californica, Baccharis pilularis, Lupinus* spp., and members of the Rhamnaceae (Howell 1949, Munz and Keck 1959, Barbour et al. 1973, Ornduff 1974, Heady et al. 1977, Grams et al. 1977). The present study concerns the history of an area north of San Francisco, Point Reyes National Seashore.

Previous studies of the past and present coastal vegetation have reached conflicting conclusions about its history, as well as its present

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composition. North of Point Reyes to the Oregon border, Burtt-Davy (1902) found a variety of species, e.g., *Erodium moschatum, Bromus rigidus, Hordeum leporinum* and *Centaurea melitensis,* invading pasture land in 1900. Based on observations of fenced-off areas, he deduced that the original forage plants had been perennial bunch grasses, chiefly *Danthonia, Stipa* and *Melica.* Wild oats (*Avena fatua*) and *Erodium* displaced these very palatable species in the 19th century as grazing pressure increased. Continued grazing led to dominance by *Hordeum jubatum, Sitanion hystrix* and *Bromus mollis* by 1900. He saw the presettlement landscape as consisting of prairies and "hard" chaparral of *Adenostema fasciculatum, Ceanothus cuneatus* and other chaparral species (Burtt-Davy 1902).

At Point Reyes, *Baccharis pilularis* dominates the coastal scrub, with at least 25% cover (Grams et al. 1977). Floristic differences in the scrub correspond with differences in exposure: on north-facing slopes *Polystichum munitum* is second in importance, whereas on south-facing slopes *Rhamnus californica* is second. Grams considered all but one of the sites to be "undisturbed" because they were not being grazed, but he did not outline the history of prior disturbance.

Also at Point Reyes, Elliott and Wehausen (1974) studied disturbance effects on deep, sandy soil in level, grazed sites. The native bunch-grass *Deschampsia caespitosa* formed denser cover in a plot ungrazed for six years than in plots continuously grazed by cattle. The growth difference may suggest a shift to prairie vegetation and is interpreted by Elliott and Wehausen as indicating that prairie was the dominant type of vegetation prior to grazing. However, *Baccharis pilularis* had the second highest cover on the plot, and *Rumex acetosella,* an introduced perennial, ranked fourth. The less heavily grazed plot had more *Deschampsia caespitosa* than the other, but also more *Baccharis pilularis.* Their study thus does not give a clear indication of the pre-grazing vegetation, whether it was grassland or scrub.

One hypothesis suggested by these earlier studies (e.g., Burtt-Davy 1902, Elliott and Wehausen 1974, Grams et al. 1977), which is tested here, is that there were major shifts in the proportion of grassland to coastal scrub taxa in the vegetation from pre-Columbian time to the present. This hypothesis would be supported by pollen records indicating changes in the ratio of grass to scrub pollen, representing a change in the ratio of prairie to scrub vegetation. The main shrubs to be considered are members of the Asteraceae, e.g., *Baccharis pilularis* and *Artemisia* spp., members of the Rhamnaceae, and *Rhus diversiloba.* The direction and timing of changes in the pollen record would suggest patterns of succession in the past.

Study Area and Methods

Point Reyes Peninsula, located at 38°N, 123°W, is separated from the mainland by the San Andreas rift zone. The base rock of Cretaceous granodiorite crops out in the northeastern part of the Peninsula and on the western tip. In most of the area the Miocene Monterey Formation, mainly bentonitic shale, overlies the granodiorite (Galloway 1977, Howard 1979). The dip of the Monterey Formation parallels the slope of the terrain, resulting in extreme landslide susceptibility in view of the bentonitic shale, high rainfall on the seaward slopes, and earthquakes (Clague 1969). These landslides have produced a landscape of steep breakaway scarps, large hummocks, and frequent lakes where slumps have dammed stream valleys (see Galloway 1977).

The climate is Mediterranean, with wet, cool winters and cool, foggy summers with little precipitation. The mean maximum temperature in July is about 16–18°C, whereas the mean minimum temperature for the same month is 11°C. Mean maximum temperature in January is 13°C, and the mean minimum is 5–7°C. Mean annual precipitation is 58–67 cm, with almost no rain falling in July–August and the maximum falling in December–February (Elford 1970). Fires in the coastal scrub are common and may alter the vegetation (Wells 1962).

Soil type maps of the Point Reyes Peninsula are not available, but generally the soil in the study area appears to be shaley clay loam over shaley clay, about 50–100 cm deep (Grams et al. 1977). There are also local shale outcrops with very shallow soil.

Wildcat Lake is located near the southwest tip of the Point Reyes National Seashore. A landslide estimated at 70,000–100,000 years B.P. blocked a valley drainage, created the lake, and left a scarp on the lake's northeast side (Fig. 1) (Clague 1969). Later slides of lesser extent left piles of debris, especially on the southeast side of the lake. The ages of these slides have not been determined.

Two sediment cores were taken in 1978 by Roger Byrne and Jeffrey Loux. One, about 50 cm long, was obtained with a 10 cm diameter plastic tube for retrieval of relatively undisturbed shallow samples. The second, 300 cm long, was obtained with a 5 cm diameter Livingstone piston corer, near the site of the first. The coring site was located in a deep part of the lake away from the inlet and outlet at the northeast end (Fig. 1).

Samples were taken from the short core at 1, 20, 30, 35, 40, 45, and 50 cm. From the long core, samples were taken at 25 cm intervals from 50 cm below the surface to 275 cm, plus one at 55 cm. All samples were prepared according to standard procedures for concentrating pollen and were mounted in silicon oil (Faegri and Iversen 1975). An average of 11,850 *Lycopodium* spores added to each sample served as a control for comparing relative concentrations of taxa in the sediment. For each sample at least 200 pollen grains were counted at 430×.

Pollen of species locally associated with wet conditions, *Alnus, Salix, Myrica,* and *Typha,* constituted a large proportion of the fossil assemblage in many samples. Changes in these obscured changes in

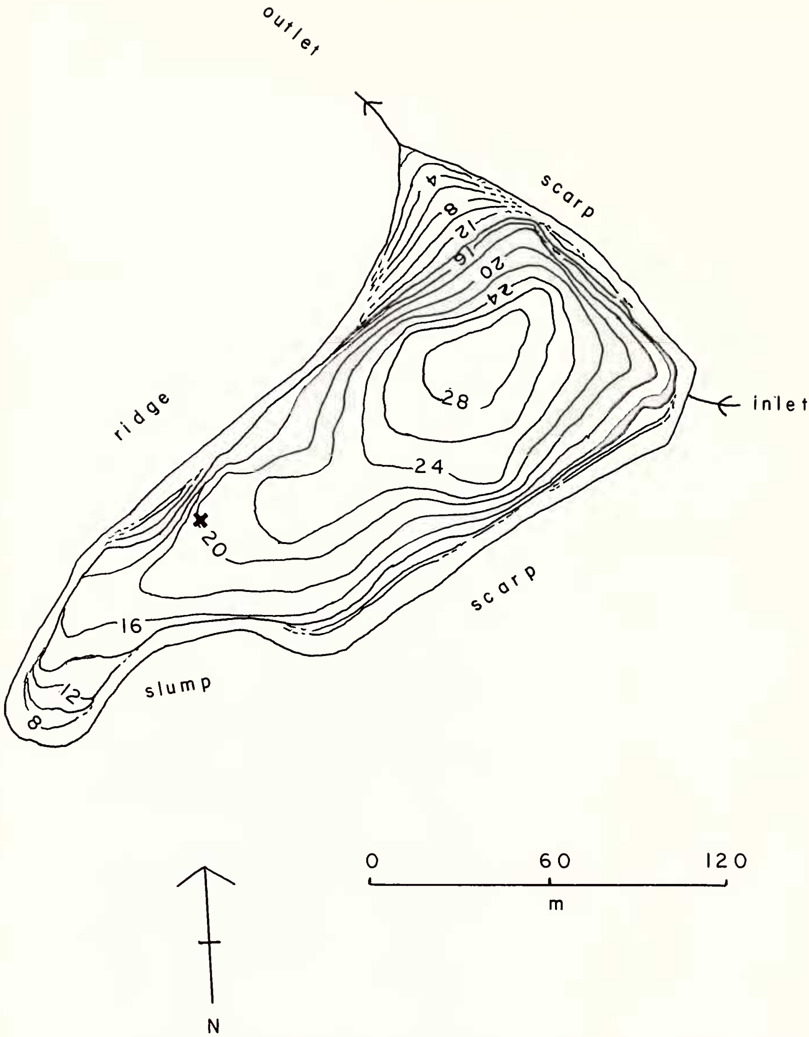

FIG. 1. Bathymetric map of Wildcat Lake, including coring site (X) (modified from Clague 1969).

the less common grass and shrub taxa. Lack of radiometric dates for the sediment and major changes in pollen influx made the use of "absolute" pollen diagrams inappropriate. Therefore pollen percents were calculated on two totals, that of the wetland species as a percent of the total and that of the remaining taxa as a percent of these taxa. This differentiation distinguished changes in local drainage patterns from changes in upland vegetation. Pollen of the wetland species was generally 30% or more of the total, indicating that it was largely locally produced. Upland pollen was blown in from varying distances (Erdtman 1969, Faegri and Iversen 1975).

To study fire history, the area covered by charcoal particles was determined on the same slides that were used for pollen counts. Only black charcoal in which cellular structure (e.g., spiral wall thickenings or bordered pits) was visible was tallied. The area covered by such a piece was determined using a reticle with unit area = 150 μm^2. The total area of charcoal for each sample was divided by the number of control grains (*Lycopodium* spores) counted on the same traverses to estimate charcoal concentration. A minimum of 10 control grains, or 10 traverses (at 430×), was counted at each level.

On 8 April and 2 June 1979, the most obvious taxa with the greatest apparent cover were noted along 12 and 17 km of trails, respectively. On 8 April, the most conspicuous members of the scrub community were *Artemisia californica, Lupinus* spp., *Rhus diversiloba, Pteridium aquilinum* and *Polystichum munitum.* Common species noticed blooming were *Lupinus* spp., *Sanicula arctopoides* on shallow soil, *Eschscholzia californica, Iris douglasii, Ranunculus* sp., *Heracleum lanatum* and *Rumex acetosella.* In the canyons where streams flowed to the ocean there were small, salt-stunted *Pseudotsuga menziesii* and some *Quercus agrifolia.* Higher up above the first range of hills *Pseudotsuga* grew much larger. Near Bass Lake and Lake Ranch, south of Wildcat Lake, were *Salix* sp., *Pseudotsuga menziesii* and *Alnus rubra.*

Near Wildcat Lake, *Baccharis pilularis* and *Rhamnus californica* were common. *Rumex acetosella* and *Plantago lanceolata* formed most of the vegetation on small paths. *Alnus rubra* grew thickly along the inlet stream, and *Salix* sp. at the outlet. *Salix* also provided dense cover in a gully at the south end of the lake. Trees on the uplands in the vicinity of the lake were *Umbellularia californica, Quercus agrifolia* and *Pseudotsuga menziesii.* The only area covered mainly with grasses in the valley around Wildcat Lake was southeast of the large slump southeast of the lake.

Results

Pollen data are given in Fig. 2. Major changes occur between levels 225 and 150 cm in the wetland species. The most salient changes are the decline in *Alnus* and *Typha* pollen from 200 cm to 150 cm and the concomitant increase of *Myrica* and *Salix.* Notable changes in "non-aquatic" pollen occur at 150–125 cm and around 50–55 cm. Near 150 cm, aquatics appear to stabilize, whereas *Sequoia* and *Artemisia* pollen percentages decline and grass pollen percentage increases. Slightly higher in the core, percent pollen of the Rhamnaceae decreases as that

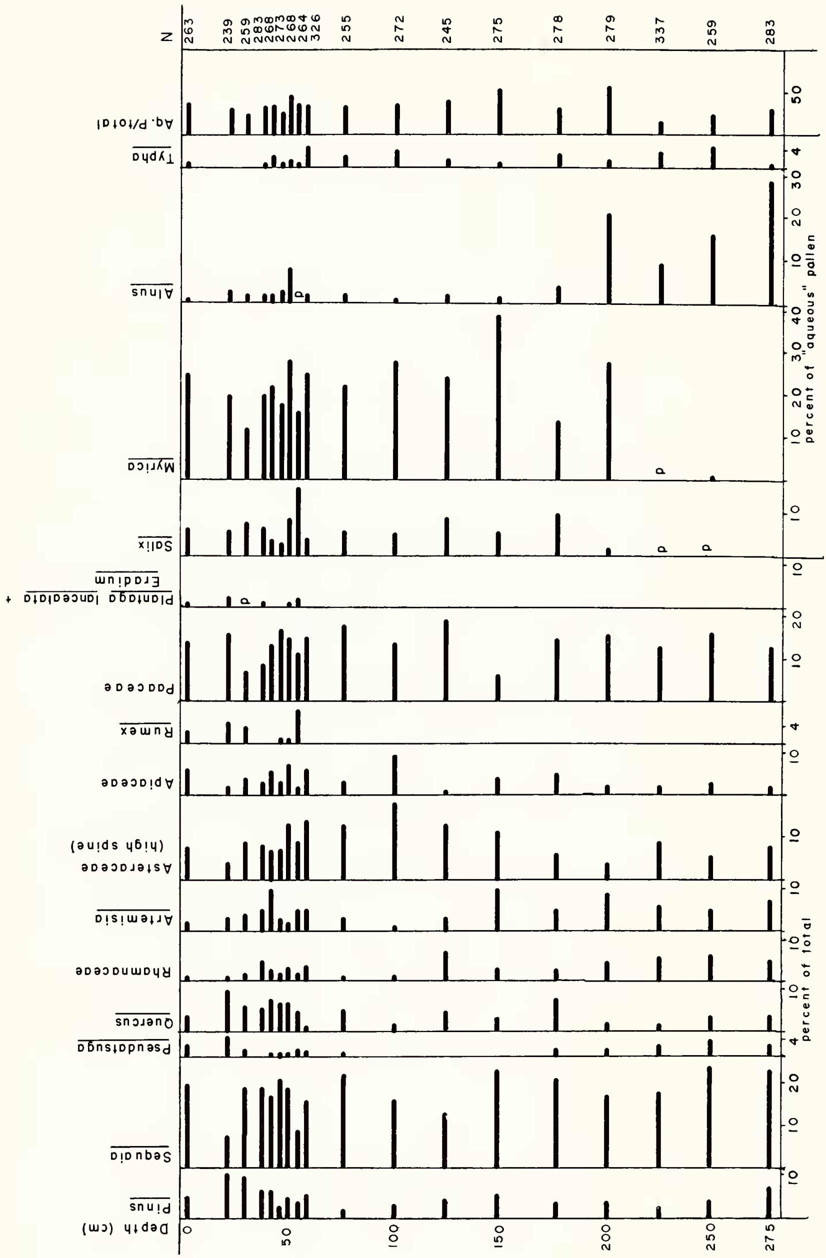

FIG. 2. Wildcat Lake pollen percentages. At the bottom of the diagram, for "percent of total" read "percent of total minus 'aqueous' pollen."

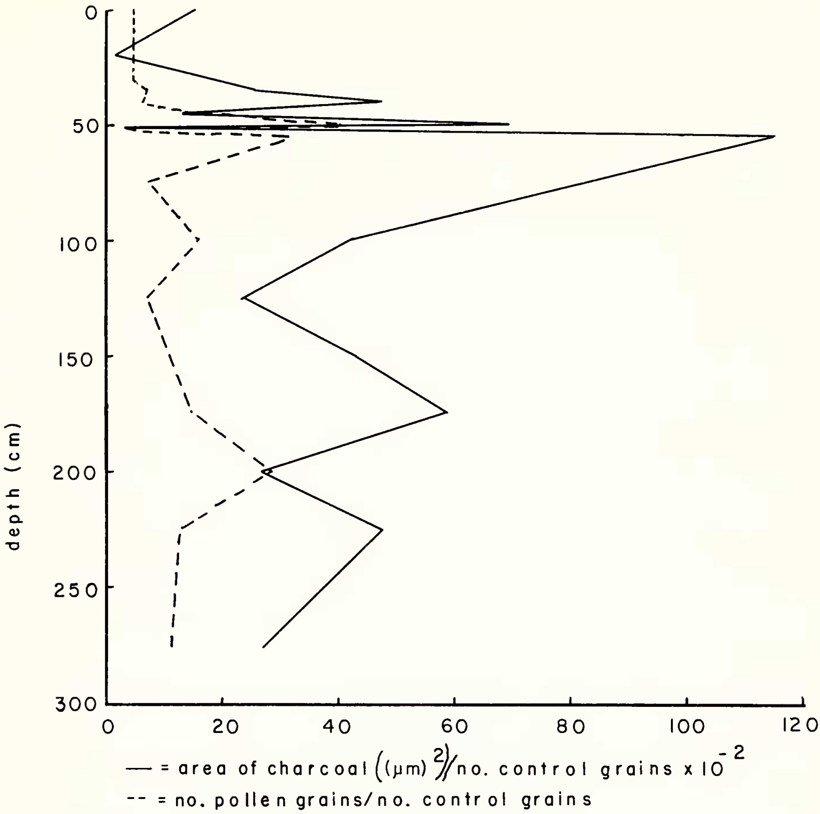

FIG. 3. Charcoal concentration in samples compared with pollen concentration in the same samples.

of the Apiaceae increases. Above about 50 cm a general increase in *Pinus* and *Quercus* pollen is accompanied by a decrease in Asteraceae and possibly in Poaceae. The 50 cm level is also marked by the appearance of the introduced European pasture weeds *Plantago lanceolata* and *Rumex acetosella* and an occasional grain of *Erodium*.

The concentration of charcoal is compared with concentration of pollen in Fig. 3. An increase in the concentration of charcoal where a similar increase does not occur in the concentration of pollen probably indicates the occurrence of a fire or fire period. Concomitant increases of pollen and charcoal are caused by changes in sedimentation, which would affect both similarly. Fires are thus indicated at 0, 40, 175, and 225 cm.

The ratio of grass pollen to shrub pollen (Fig. 4) ranges from 1.2:1 to 0.3:1, with a mean of about 0.8:1. The low corresponds with a peak

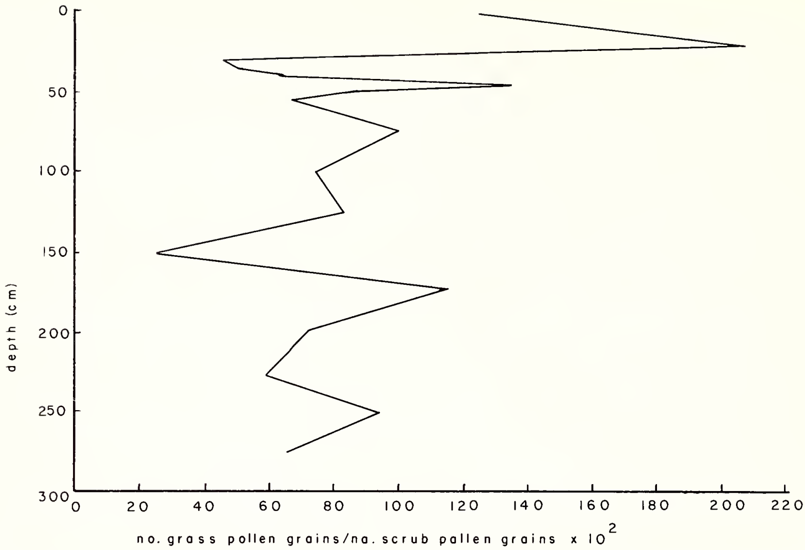

FIG. 4. Ratio of grass (Poaceae) pollen to scrub (Asteraceae, including *Artemisia,* Rhamnaceae, *Rhus*) pollen.

in *Myrica* pollen at 150 cm. This fluctuating ratio becomes slightly higher (1.0:1) and fluctuates more above 50 cm.

DISCUSSION

The most precise date in the pollen core is the first appearance of pollen of introduced taxa, *Rumex acetosella* and *Plantago lanceolata,* at 50 cm (Fig. 2). Historical data place this near 1850 A.D. The core was taken in 1978, indicating a sedimentation rate of 50 cm/128 yr, or 0.39 cm/yr. Extrapolation of this rate to sediment below this point gives a minimum estimate of 1275 A.D. for the age of the sediment. Erosion accelerated by grazing, which increased the input of sediment to the lake, plus compaction at lower levels make this a very conservative estimate of the age of the bottom of the core.

The variations in the ratio of grass pollen to shrub pollen (Fig. 4) support the hypothesis that the ratio of grassland to scrub has changed in the past. Fluctuations in the proportion of grassland seem to have occurred before European settlement of the area. It appears likely that the precolonial landscape contained a mixture of prairie and chaparral vegetation, as suggested by Burtt-Davy (1902). The areas studied by Elliott and Wehausen (1974) and Grams et al. (1977) may represent naturally occurring temporal and spatial variation in the mosaic of vegetation.

The low ratio of grass to shrub pollen at 150 cm, which corresponds with a peak in *Myrica* pollen, may be associated with a fire, because *Myrica* spreads rapidly after fires (Howell 1949). Very high charcoal counts at about 175 cm (Fig. 3) show the possibility of a fire at that level. The fire may have been followed by the spread of *Myrica* and fire-stimulated scrub species, and a temporary low period of grass growth.

That grass pollen is generally less common than the scrub species cannot, by itself, be taken as evidence that scrub was more common than prairie. Differential production and dispersal of pollen alone may have caused this difference if the scrub species produce more pollen per unit area than the grasses. However, the increased fluctuations in the ratio after European settlement, and the higher grass pollen in some samples, suggest that increased exploitation of the land by grazing increased grassland at the expense of shrubs.

The pollen evidence of wetland species (Fig. 2) raises another issue. It appears that sudden changes have occurred in local drainage over the period sampled by this core. These changes, probably associated with landslides, have occurred since the formation of the lake. Above 200 cm the dramatic decrease in alder pollen strongly indicates a reduction in the habitat of alder, which in this area is generally along streambanks. One may surmise that at this time there was a local landslide or slump that slowed the flow of water in a nearby stream such that the alder no longer had a suitable habitat locally. Then the increased swampy area was invaded by *Salix,* which presently forms a nearly impenetrable thicket at the outlet of the lake near the north end. The simultaneous decline of *Typha* pollen could be related to slump filling of the shallow littoral site formerly occupied by *Typha. Myrica* may have invaded the disturbed habitat formed by the slump debris.

Pseudotsuga, which grows on the ridge east of the lake, is represented in the pollen record with a maximum of six percent. This confirms Erdtman's (1969) statement that *Pseudotsuga* pollen has very low powers of dispersal.

After European settlement, the relative amounts of *Pinus* and *Quercus* pollen increased and, at least at one point, the amount of *Sequoia* pollen declined sharply. A decline in Asteraceae and Poaceae pollen is associated with the increases in *Pinus* and *Quercus* pollen. This might correspond with the type of grazing landscape described by Lapérousse in 1786, in which a few trees were left in cattle pastures for shade (Lapérousse 1937). The grazed Poaceae and Asteraceae produced little pollen, whereas the trees may have produced more copiously than when in a thicker stand. Scrub, consisting largely of *Artemisia* and Rhamnaceae, persisted outside the pastures (Lapérousse 1937, Beechey n.d.). The sudden drop in *Sequoia* pollen and subsequent recovery above 30 cm probably indicates the heavy logging of this species in the early 20th century. The peak of *Salix* pollen at 50 cm may suggest that Judge Shafter, who owned this land in the late 19th century, tried to use *Salix* as a living fence in places, as did ranchers in the southern part of the state (Fabian 1869).

The vegetation in this area presents a basic pattern in which the non-arboreal pollen remains near 40% of the total. The most important upland taxa are Poaceae, Asteraceae (including *Artemisia*) and *Sequoia,* the latter blown in from a distance. However, shifts in the relative abundances of these pollen taxa indicate changes in the vegetation during the centuries preceding European settlement in addition to changes caused by European settlement. Causes of the pre-Columbian changes are unknown, but topographic disturbances in the area are indicated by sudden shifts in taxa whose distribution is related to changes in local drainage. We may thus see a superposition of topographic disturbance on a system adapted to the local climate, soils and topography.

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